Mars Orbital Lidar for Global Atmospheric and Topographic Measurements

James B. Abshire, Michael D. Smith, Haris Riris, Xiaoli Sun
NASA-Goddard, Solar System Exploration Division, Greenbelt MD 20771, James.B.Abshire@nasa.gov

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1. Introduction: We are conducting studies on an atmospheric lidar for Mars climate measurements. Our work is developing a preliminary design and performance estimates for a direct detection lidar (Fig. 1) that continuously measures atmospheric backscatter profiles, depolarization profiles, Doppler shift (wind profiles) and column water vapor. These measurements directly address high priority needs for Mars as identified in the Chapter 6 of the 2011 Planetary Decadal Survey, as well as strategic knowledge gaps recently identified in NASA's reformulated Mars program.

The targeted lidar is MOLA instrument-sized (a ~80 cm cube, Fig 2) that uses the direct detection technique. The dust, ice and Doppler measurements will be made at 532 or 1064 nm. The water vapor profiles will be measured with a wavelength-shifted output of the laser that is tuned on- and off- a water vapor (WV) absorption line in the NIR-IR. The time of flight of the surface echo pulse can be used to measure surface height. We are planning on using a Nd:YAG laser, a ~50-70 cm receiver telescope and detectors with high sensitivity and TRL.

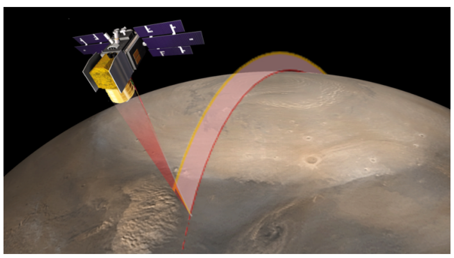

Fig 1- Measurement Concept

2. Mars atmosphere and needed measurements: Although considerable progress has been made, knowledge of the present Mars atmosphere is limited by a lack of observations in several key areas including diurnal variations of aerosols, water vapor and direct measurements of wind velocity [1]. For example, both MGS and MRO observed only afternoon and early morning local time. Both dust and water ice aerosols are pervasive in the Mars atmosphere. Dust interacts strongly with IR radiation causing large changes in the thermal structure and acting as a driver of atmospheric motions at all spatial scales. Water ice clouds play an important role in the water cycle altering the global transport of water vapor. The limited local time coverage of observations to date has shown large changes in the amount and vertical distribution of dust and ice aerosols and water vapor. However, existing observations do not allow the full diurnal cycle of water vapor, dust and ice aerosols to be characterized.

Winds on Mars also play a fundamental role, yet basic questions still remain about the 3-D wind structure and how it changes with local time, location, and season. Despite low atmospheric density, the winds are often strong enough to raise large amounts of dust from the surface, and at times the planet can become almost completely enshrouded in it. The winds transport water vapor, dust and ice aerosols, and mix all atmospheric gaseous constituents. Winds regulate the transfer of water vapor and heat throughout the atmosphere and are a primary player in all surface-atmosphere interactions. Wind velocities provide sensitive input and validation for Global Circulation Models (GCMs), and knowledge of winds is of critical for the safety and precision of spacecraft entry, descent and landing (EDL). Despite the importance of winds on Mars, presently there are only a few direct observations of them [2], and indirect inferences are often imprecise and contain many assumptions.

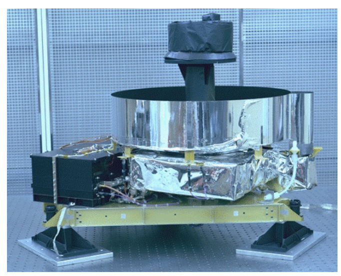

Fig 2- MOLA lidar flown on MGS

New observations by an orbital lidar can give simultaneous measurements of water vapor column density along with dust and ice aerosol vertical profiles over a full range of local times, providing a self-consistent description of the water cycle over the entire diurnal cycle and its relationship to dust. Direct lidar measurements of height resolved wind velocities would provide a new and critical dataset. Together, these observations would allow significantly improved EDL modeling and would provide a powerful new tool for understanding many important processes in the atmosphere, including circulation patterns, waves, radiative balance, the transport, sources and sinks of trace gases.

3. Lidar measurements of planetary atmospheres: This approach builds on several successful space lidar missions and instruments. Orbital lidar have been used to make uniquely valuable measurements of vertically resolved scattering in the Earth's atmosphere. The Calipso Mission [3] has made nearly continuous measurements of vertically and polarization-resolved scattering at both 532 and 1064 nm from Earth orbit over a 6-years. During its Campaign 2a, the GLAS lidar on ICESat [4] also measured atmospheric backscatter profiles with a photon counting receiver at 532 nm, which demonstrated even higher backscatter sensitivity [5].

Scattering in the Mars atmosphere has been measured with lidar on two missions. The MOLA investigation [6] on MGS also recorded and analyzed backscatter and attenuation from globally distributed clouds and dense aerosols [7]. The Phoenix lander mission also carried a highly successful lidar that measured atmospheric backscatter profiles and falling precipitation from a fixed surface location [8,9].

ESA is currently completing a wind lidar for Earth orbit [10], and an airborne version has been demonstrated [11]. These measure the Doppler shift of the height resolved backscatter along the laser's line-of-sight with a UV laser and dual-interferometer-based receiver. Airborne lidar have been used to measure atmospheric water vapor profiles [12]. Airborne lidar measurements of column CH4 density have been demonstrated recently (see Fig. 3) using the IPDA technique [13]. All of these lidar have used diode-pumped Nd:YAG lasers and direct detection receivers.

Table 1 – Mars orbital lidar nominal parameters.

Nominal Orbit:	Polar, Circular, 400 km alt.
Viewing angle:	20-30 degrees off-nadir
Prime measurements:	• Backscatter profiles
(along line-of-sight)	• De-polarization profiles
	• Profiles of Doppler shift
	• WV column absorption
Atmos. profile resolution	~ 1 km in height
Laser type:	Nd:YAG + λ- converters
Telescope diameter:	50-70 cm
Receiver approach:	Direct Detection

4. Lidar approach: Our approach is to use a narrow linewidth laser that operates with modest energy at kHz pulse rates. A doubler will be used to generate 532 nm for the aerosol and Doppler measurements. A seeded wavelength down-converter is used to generate NIR radiation that will be rapidly tuned on and off a water vapor line for IPDA measurements. The receiver uses a beam splitter to separate the wavelengths and an optical interferometer to resolve the Doppler shift in the backscatter profiles. Figure 4 shows an instrument diagram and some parameters are in Table 1. More details will be given in the presentation.

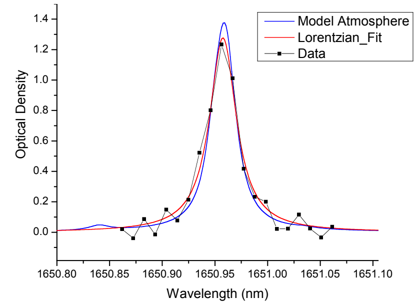

Figure 3- Airborne lidar measurements of CH4 line shape in column from 10 km to surface [13].

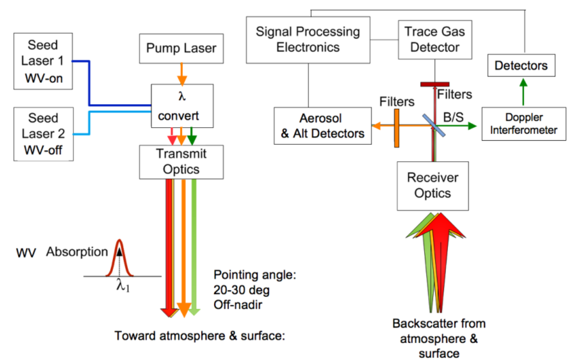

Figure 4 – Mars orbital lidar measurement approach

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